PB-244 415

PRELIMINARY ASSESSMENT OF SUSPECTED CARCINOGENS IN DRINKING WATER

ENVIRONMENTAL PROTECTION AGENCY

JUNE 1975

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PRELIMINARY ASSESSMENT OF SUSPECTED CARCINOGENS IN DRINKING WATER

INTERIM REPORT TO CONGRESS

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16. ABSTRACT

The Report is a compilation of the efforts ongoing in EPA to identify the nature and extent of the contamination of the nation's drinking water, to determine the possible health effects of exposure, and to develop the technically and economically feasible means of removing those contaminants of concern. It was prepared in response to the Section 1442(a)(9) of the Safe Drinking Water Act. It is accompanied by an Appendix which presents the technical details of many of the studies described more briefly in the Report.

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PRELIMINARY ASSESSMENT OF SUSPECTED CARCINOGENS IN DRINKING WATER

AN INTERIM REPORT TO CONGRESS

Compiled by
Office of Toxic Substances
Environmental Protection Agency
Washington, DC 20460
June 1975

INTRODUCTION

For decades most Americans have confidently relied upon their public drinking water, assuming that the Nation's drinking water was free of microbiological and other harmful contaminants. In view of recent findings, however, the assumption that our water is "safe" is subject to question. Investigations have found that outbreaks of disease or poisoning attributed to drinking water have not been completely eliminated. Also of concern are recent findings that our drinking water contains substances which are believed to be potentially carcinogenic or otherwise toxic, such as various organic chemicals, certain heavy metals, radionuclides, and asbestos.

On December 16, 1974, the Safe Drinking Water Act became law, requiring the Administrator of the Environmental Protection Agency (EPA) to promulgate national drinking water standards. While this legislation was being deliberated by Congress, the discovery of asbestos fibers in the water supply of Duluth, Minnesota, alerted the nation to the contamination of some water supplies with asbestos, a suspected carcinogen in drinking water. In November 1974, EPA announced that small quantities of 66 organic chemicals, some of which were suspected carcinogens, were found in the New Orleans drinking water supply. Partially in response to these events, Congress passed an amendment which became Section 1442(a)(9) of the Safe Drinking Water Act. This Section directs the Administrator to make "a comprehensive study of public water supplies and drinking water sources to determine the nature, extent, sources of and means of control of contamination by chemicals or other substances suspected of being carcinogenic."

This interim Report is in response to that mandate and presents the current programs of EPA to identify the nature and extent of the contamination of the Nation's drinking water, to determine the possible health effects of exposure, and to develop the technically and economically feasible means of removing those contaminants of concern. In many cases, however, the projects discussed are just underway or in various stages of completion. Therefore, much of this Report is preliminary and may be considerably revised and expanded at a later date.

While the criteria for predicting the carcinogenic potential of chemicals have been reviewed extensively during the last decade and many experts have agreed on certain guidelines, there is no official consensus on what evidence is required to categorize a substance as "carcinogenic". Thus, the Report considers a large number of chemicals in addition to those that may have been rather conclusively established as carcinogens. Further, there has been no attempt to distinguish between those "suspected carcinogens" which are generally recognized as carcinogenic and those with questionable carcinogenic potential.

Most suspected carcinogens are hazardous because of their chemical properties. On the other hand, asbestos is believed to be potentially carcinogenic because of its physical properties. This Report will deal with the two main groups of chemical carcinogens, organic and inorganic, and separately with asbestos.

Organics, such as pesticides and other petrochemical products, have long been a concern of the U.S. Public Health Service. A 1970 survey discovered that the levels of organics in many water supplies exceeded the Public Health Service's recommended limit for carbon chloroform extractable organics, which at that time was 200 micrograms per liter.[1] In 1972, EPA reported that 46 organic chemicals were present in trace amounts in the raw and finished water supplies of three locations along the Lower Mississippi;[2] a 1974 EPA study identified 66 organics in New Orleans drinking water.[3] These and similar findings led to the initiation of the National Organics Reconnaissance Survey to help clarify the extent that organics are present in the Nation's drinking water.

Many inorganic chemicals in drinking water could cause adverse health effects at certain concentrations. The proposed Interim Primary Drinking Water Regulations published on March 14, 1975, call for maximum contaminant levels for 11 inorganics as well as for organics and microbiological contamirants. While the Regulations call for maximum levels for nine specific pesticides, there is a maximum contaminant level for the total concentration of organics, as measured by the carbon chloroform extract method. The inorganic chemicals limited by the Regulations are: arsenic, barium, cadmium, chromium, cyanide, fluoride, lead, mercury, nitrate, selenium, and silver. Arsenic is both toxic and widespread throughout the environment, finding its way into drinking water from natural deposits and from its use as a pesticidal agent. Lead is another example of a toxic substance which is found in food, air, and water. Other standards, and revision of the present standards, will be proposed as more is learned about the contaminants in drinking water and their toxicity and pathways to man.

Radionuclides may present a hazard for which there may be no harmless level. A great diversity of sources are associated with radionuclides and their occurrence in drinking water supplies varies widely. While man-made sources such as effluent from nuclear facilities may be controllable, natural sources of radioactivity are not as easily controlled. Certain water treatment techniques and alternative water supplies may reduce the exposure to radionuclides from drinking water sources. At this time, proposed

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[1] Community Water Supply Study -- Analysis of National Survey Finding. Bureau of Water Hygiene, U.S. Public Health Service, July 1970.

[2] Industrial Pollution of the Lower Mississippi River in Louisiana, Environmental Protection Agency, April 1972.

[3] New Orleans Area Water Supply Study, Environmental Protection Agency, Draft report released on November 8, 1974.

maximum contaminant levels for radioactive materials in drinking water have been prepared and are being circulated for interagency review.

While inhaled asbestos is considered a carcinogen as the result of numerous toxicological and epidemiological studies, whether asbestos ingested in food or water is carcinogenic is unclear. In addition to industrial discharges of asbestos, other sources of asbestos, such as naturally occurring asbestos, may also be contaminating drinking water supplies with potentially hazardous levels of asbestos.

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SUMMARY

The Environmental Protection Agency has been conducting an extensive program to answer the questions being raised by Congress and the Nation concerning suspected carcinogens in drinking water. An early step initiated last November is the National Organics Reconnaissance Survey, designed to provide an estimate of the nationwide distribution of organics in drinking water. The initial results of this survey, included in this Report, show that small quantities of organics are present in all of the 80 drinking water supplies surveyed. Further analyses of the data collected and a comprehensive survey of organics in ten water supplies will be completed by December 1975. Other projects involve surveillance and analysis of drinking water for selected inorganics, pesticides, and asbestos. Results for many of these studies will be available within the next two years.

Concurrent with the efforts to determine the presence of contaminants, EPA has numerous studies to evaluate the health effects of these substances in drinking water. The National Academy of Sciences is conducting a two-year study concerning the relationship between various contaminant levels and health effects. This effort should provide important information for setting national contaminant levels. EPA's Science Advisory Board recently reported its findings on the potential carcinogenic effects from exposure to certain organics in drinking water.[4] The report emphasized the great need for well-designed experimental studies on the effects of lifetime exposure by ingestion of the compounds found in drinking water. EPA has been conducting preliminary investigations to evaluate the toxicity of several individual compounds and mixtures of organics. Other efforts include examination of the health effects of naturally occurring organics (humic substances) and some epidemiological studies of the effects of organics. In addition, investigations of the health effects of selected inorganics and of asbestos involve many studies, including a four-year asbestos feeding study expected to begin shortly.

As part of the strategy to develop the basis for controlling contaminants in drinking water, EPA is identifying the possible sources of organics: industrial effluents and waste management practices, discharge from municipal waste treatment facilities, chlorination processes, and runoff of agricultural chemicals. Various treatment techniques such as the use of granular activated carbon are being tested for removal of organics and other drinking water contaminants. Finally, EPA is developing estimates of the possible costs and economic impact of controlling contaminants in drinking water.

[4] A Report: Assessment of Health Risk from Organics in Drinking Water, Hazardous Materials Advisory Committee, Science Advisory Board, Environmental Protection Agency, May 19, 1975.

CHARACTER AND EXTENT OF CONTAMINATION OF WATER SUPPLIES

On April 18, 1975, EPA announced the preliminary results of a nationwide survey for organics in drinking water. This National Organics Reconnaissance Survey is one of several efforts underway to investigate the possible problem of suspected carcinogens in drinking water. Another investigation is focusing on whether drinking water is a significant source of three pesticides (aldrin, dieldrin, and DDT). Previous EPA work uncovered a significant number of people carrying disturbing traces of dieldrin in their blood and body tissues.

In addition to the studies of organic contaminants, inorganic chemicals, especially those which are included in the proposed Interim Primary Drinking Water Regulations, are the subject of monitoring and analysis efforts. A special assessment of rural drinking water supplies is being considered and a study of asbestos in drinking water is underway. This section discusses these and other programs to determine the nature and extent of contamination of the Nation's drinking water supplies.

National Organics Reconnaissance Survey

One of the Agency's most significant efforts to delineate the problem of organics in drinking water is the National Organics Reconnaissance Survey. Initiated in November 1974, the National Organics Reconnaissance Survey has three major objectives. One is to determine the extent of the presence of the four trihalomethanes: chloroform (trichloromethane), bromodichloromethane, dibromochloromethane, and bromoform (tribromomethane) in finished water, and to determine whether or not these compounds are formed by chlorination. The second objective is to determine the effects raw water source and water treatment practices other than chlorination could have on the formation of these compounds. The third objective is to characterize, as completely as possible using existing analytical techniques, the organic content of ten finished drinking water supplies. These ten supplies represent five major categories of raw water sources in use in the United States today.

Survey of Eighty Water Supplies for Selected Contaminants

Eighty water supplies were chosen to determine the presence of six specific organics of particular concern: the four trihalomethanes (chloroform, bromodichloromethane, dibromochloromethane, and bromoform), carbon tetrachloride, and 1,2-dichloroethane. Selected in consultation with State water supply officials, these 80 supplies provide a reasonably representative sample of the Nation's community drinking water supplies that chlorinate their water, representing a wide variety of raw water sources, treatment techniques, and geographical locations. Based on the survey findings, it appears that chlorination contributes to the formation of the four trihalomethanes. Results from the analysis of the raw or untreated water samples showed that none of the samples contained any dibromochloromethane or bromoform, and only 62 percent of the samples contain any chloroform or bromodichloromethane. Of these samples, 58.4 percent contained very small concentrations of chloroform, 0.1 to

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0.9 µg/l; the other 3.6 percent contained no chloroform but had low concentrations of bromodichloromethane, 1,2-dichloromethane, and/or carbon tetrachloride in various combinations. Table 1 presents results of the analysis of raw water.

Table 1

RAW WATER ANALYSIS
(Based on 79 samples)

	Number of Locations Detected	Range of Concentrations (µg/liter)
None Detected	30	-
Chloroform	45	<0.1 - 0.9*
Bromodichloromethane	6	<0.2 - 0.8*
Dibromochloromethane	0	- *
Bromoform	0	-
1,2-Dichloroethane	11	<0.2 - 3
Carbon Tetrachloride	4	<2 - 4

*One additional location received raw water prechlorinated by a nearby industry. This water contained 16 µg/l of chloroform, 11 µg/l bromodichloromethane, and 3 µg/l dibromochloromethane.

In contrast to these findings for raw water, the presence of the four trihalomethanes, although mostly in low concentrations, was widespread throughout the finished water. In all the locations, the finished water treated or contained chloroform in concentrations ranging from less than 0.1 µg/l to 311 µg/l, with 50 percent of the finished waters containing 25 µg/l of chloroform or less. Bromodichloromethane was in 97.5 percent of the finished waters in concentrations of 0.3 µg/l to 115 µg/l, with 62 percent of these containing 10 µg/l or less. Dibromochloromethane appeared in 90 percent of the locations in concentrations from less than 0.4 µg/l to 100 µg/l, with 75 percent of these locations having 5 µg/l or less. Finally, bromoform was found in 31.6 percent of the finished waters in concentrations ranging from 0.8 µg/l to 92 µg/l, with 95 percent of these having 5 µg/l of bromoform or less.

Only very small amounts of 1,2-dichloroethane and carbon tetrachloride were found in the finished waters. Of the supplies that contained 1,2-dichloroethane, 32.9 percent of the total, 6 µg/l was the highest concentration found; of the 12.6 percent of the systems with carbon tetrachloride, the highest level was 3 µg/l. Table 2 shows the distribution and range of concentrations of the trihalomethanes, 1,2-dichloroethane, and carbon tetrachloride in finished water. Table 3 presents the results of the analyses of the finished water for each of the 80 cities.

Table 2

FINISHED WATER ANALYSIS
(Based on 79 samples)

Compound	Number of Locations Detected	Range of Concentrations (µg/liter)
Chloroform	79	0.1 -- 311
Bromodichloromethane	76	1.8 -- 116
Dibromochloromethane	70	0.4 -- 100
Bromoform	25	1.0 -- 92
Carbon Tetrachloride	10	2.0 -- 3
1,2-Dichloroethane	26	0.2 -- 6

Survey of Ten Water Supplies for Broad Range of Organics

The second principal component of the National Organics Reconnaissance Survey included ten of the 80 cities as sites representing five major categories of raw water sources for a more comprehensive survey of the organic content of finished water. The first five cities investigated and their raw water sources are: Miami, Florida (ground water); Seattle, Washington (uncontaminated upland water); Ottumwa, Iowa (raw water contaminated with agricultural runoff); Philadelphia, Pennsylvania (raw water contaminated with municipal waste); and Cincinnati, Ohio (raw water contaminated with industrial discharges).

Preliminary analyses of the drinking water of these five cities have identified over 85 organics, as indicated in Table 4. More analyses were performed than are included; however, only those constituents that were qualitatively or quantitatively determined to be present are included. Different techniques were used to identify as broad a range of organic compounds as possible. One technique was designed for the more volatile organics. Details of all procedures are found in Appendix III.

Within the next six months, the water supplies of the five remaining cities will be surveyed and the results are expected to be reported by the end of the year. These five cities and their raw water sources are: Tucson, Arizona (ground water source); New York, New York (uncontaminated upland water); Grand Forks, North Dakota (water contaminated by agricultural runoff); Terrebonne Parish, Louisiana (water contaminated by municipal waste); and Lawrence, Massachusetts (water contaminated by industrial discharges).

Table 3

FINISHED WATER DATA FOR EIGHTY CITIES

	Chloroform µg/l	Bromo dichloro methane µg/l	Dibromo chloro-methane µg/l	Bromo form µg/l	1,2 Dichloro-ethane µg/l	Carbon Tetra-chloride µg/l	Non Volatile Total Organic Carbon mg/l
ALASKA, Douglas	40	0.8	<0.4	NF	NF	NF	2.8
ARIZONA, Phoenix	9	15	17	<4	NF	NF	1.0
Tuscon	<0.2	<0.8	2	13	NF	NF	<0.05
ARKANSAS, Camden	40	19	7	NF	NF	NF	1.5
CALIFORNIA, Coalinga	16	17	15	2	NF	NF	2.4
Concord	31	18	6	<1	NF	NF	1.9
Dos Palos	61	53	34	7	NF	NF	2.9
Los Angeles	32	6	3	NF	NF	NF	1.3
San Diego	52	30	19	3	NF	NF	2.8
San Francisco	41	15	4	<0.6	NF	NF	1.6
COLORADO, Denver	14	10	3	NF	NF	NF	1.7
Pueblo	2	2	<2	NF	NF	NF	1.6
CONNECTICUT, Waterbury	93	10	0.6	<1	<0.2	<2	2.9
DELAWARE, Newark (Artesian Water Co.)	0.5	0.5	1	<1	<0.2	NF	0.2
Wilmington Sub.	23	11	3	NF	<0.4	<2	1.8
DISTRICT OF COLUMBIA Washington	41	8	2	NF	<0.3	NF	1.2
FLORIDA, Jacksonville	9	4	2	NF	NF	NF	2.3
Miami	311	78	35	3	<0.2	NF	5.4
GEORGIA, Atlanta	36	10	2	NF	NF	NF	0.9
IDAHO, Idaho Falls	2	3	3	NF	NF	NF	0.3
ILLINOIS, Chicago	15	10	4	NF	<0.4	NF	1.5
Clinton	4	0.5	NF	NF	NF	NF	6.7
INDIANA, Indianapolis	31	8	<2	NF	NF	2	2.6
Whiting	0.5	0.3	NF	NF	NF	NF	1.5
IOWA, Clarinda	48	19	4	NF	NF	NF	3.0
Davenport	88	8	<0.6	NF	<0.4	NF	4.4
Ottumwa	0.8	NF	NF	NF	NF	NF	2.3 (2/17/75)
Ottumwa	1	NF	NF	NF	NF	NF	2.4 (4/7/75)
KENTUCKY, Owensboro	13	20	17	3	NF	NF	2.0
KANSAS, Topeka	88	38	19	5	NF	3	2.2
LOUISIANA, Logansport	28	39	24	3	NF	NF	3.5
Terrebonne Parish	134	32	8	<1	0.2	NF	3.2

NF - None Found

Table 3 (cont.)

FINISHED WATER DATA FOR EIGHTY CITIES

	Chloroform ug/l	Bromo-dichloro-methane ug/l	Dibromo chloro-methane ug/l	Bromo form ug/l	1,2-Dichloro-ethane ug/l	Carbon Tetra-chloride ug/l	Non Volatile Total Organic Carbon mg/l
MARYLAND, Baltimore	32	11	2	NF	NF	NF	1.2
MASSACHUSETTS, Boston	4	0.8	NF	NF	NF	NF	2.0
Lawrence	91	9	0.6	NF	NF	NF	1.6
MICHIGAN, Detroit	12	9	3	NF	0.4	NF	1.2
Mt. Clemens	11	6	2	NF	<0.4	NF	1.4 (2/3/75)
Mt. Clemens	6	3	2	NF	NF	NF	1.4 (3/25/75)
MINNESOTA, St. Paul	44	7	<2	NF	NF	NF	4.4
MISSISSIPPI, Greenville	17	6	3	<1	<0.2	NF	4.0
MISSOURI, Cape Girardeau	116	21	2	NF	0.3	2	3.6
Kansas City	24	8	2	NF	NF	NF	1.9
St. Louis	55	13	3	<1	0.4	NF	2.6
NEBRASKA, Lincoln	4	6	4	<2	NF	NF	1.4
NEW JERSEY, Passaic Valley	59	16	2	NF	<0.2	<2	1.9
Toms River	0.6	<0.8	3	NF	NF	0.05	
NEW MEXICO, Albuquerque	0.4	1	2	3	NF	NF	0.05
NEW YORK, Buffalo	10	10	4	NF	<0.2	NF	1.7
New York	22	7	0.9	NF	NF	NF	2.5
Rhinebeck	49	11	1	NF	2	NF	1.6
NORTH DAKOTA, Grand Forks	3	1	NF	NF	NF	NF	5.2
OHIO, Cincinnati	45	13	4	NF	<0.4	<2	1.1
Cleveland	18	9	4	NF	NF	NF	1.8
Columbus	134	8	<0.4	NF	NF	NF	2.3
Dayton	8	8	11	4	<0.2	<2	0.7
Indian Hill Water-works	5	7	11	NF	NF	NF	0.9
Piqua	131	13	3	NF	<0.2	NF	4.2
Youngstown	80	5	<1	NF	NF	NF	3.1
OKLAHOMA, Oklahoma City	44	28	20	6	<0.4	<2	2.8
OREGON, Corvallis	26	3	NF	NF	NF	NF	0.4
PENNSYLVANIA, Philadel-phia	86	9	5	NF	6	NF	1.7
Pittsburgh	8	2	0.4	NF	NF	NF	0.8
Strasburg	<0.1	NF	NF	NF	NF	NF	0.05
PUERTO RICO, San Juan	47	29	16	2	NF	NF	2.0
RHODE ISLAND, Newport	103	42	13	1	NF	NF	4.1
SOUTH CAROLINA, Charles-ton	195	9	0.8	0.8	NF	NF	4.1
SOUTH DAKOTA, Huron	309	116	49	8	NF	NF	12.2
TENNESSEE, Chattanooga	30	9	0.7	NF	<0.4	NF	0.6
Memphis	0.9	2	1	NF	NF	NF	0.2
Nashville	16	5	<0.4	NF	NF	NF	0.8

Table 3 (cont.)

FINISHED WATER DATA FOR EIGHTY CITIES

	Chloroform ug/l	Bromo-dichloro-methane ug/l	Dibromo chloro-methane ug/l	Bromo form ug/l	1,2-Dichloro-ethane ug/l	Carbon Tetra-chloride ug/l	Non-Volatile Total Organic Carbon mg/l	
TEXAS, Brownsville	12	37	100	92	NF	NF	3.1	
Dallas	18	4	<2	NF	NF	NF	2.9	
San Antonio	0.2	0.9	3	3	NF	NF	0.5	
UTAH, Salt Lake City	20	14	8	NF	NF	NF	0.9	
VIRGINA, Annandale	67	6	<0.6	NF	NF	NF	2.7	
Hopewell	6	1	0.8	<2	NF	NF	0.2	
WASHINGTON, Ilwaco	167	35	5	NF	NF	NF	3.1	
Seattle	15	0.9	NF	NF	NF	NF	0.9	(End of Dist. System)
WEST VIRGINA, Huntington	23	16	5	NF	<0.4	3	1.0	
Wheeling	72	28	17	NF	<0.4	NF	1.8	
WISCONSIN, Milwaukee	9	7	3	NF	<0.2	NF	1.7	
Oshkosh	26	4	<0.4	NF	<0.2	NF	3.3	

Table 4

ORGANIC COMPOUNDS DETECTED IN SURVEY OF FIVE CITIES
(Approximate Concentrations, µg/l)

	Miami, Florida	Seattle, Washington	Ottumwa, Iowa	Philadelphia, Pennsylvania	Cincinnati, Ohio
1. acetaldehyde	X	0.1	X	0.1	X
2. acetone	X	1	X	X	X
3. acetophenone				1	
4. acetylenebromide	X				
5. acetylenechloride	X				
6. acetylenedichloride	X			X	X
7. atrazine			0.1		
8. benzene	X		X	X	X
9. benzoic acid			15		
10. bis2-(chloroethyl)ether				0.5	
11. 1,2-bis(2-chloroethoxy)ethane				0.03	
12. bromodichloromethane	78	0.9	X	9	13
13. bromoform	1.5			X	X
14. bromomethane	X				
15. 2-butanone		X	X	X	X
16. t-butyltoluene				0.01	
17. camphor	0.5	0.5	0.1		0.1
18. carbon disulfide	X				X
19. carbon tetrachloride	X		X	X	X
20. chloral (trichloroacetaldehyde)		3.5		5	2
21. chlorobenzene	1.0			X	X
22. chloroethane	X			X	X
23. chloroform	311	15	1	86	45
24. chloromethane	X		X	X	X
25. chloropicrin (trichloronitromethane)			0.05		
26. p-chlorotoluene	1.5				
27. cyanogen chloride			0.1		
28. cymene isomer	0.1				
29. cyclohexanone	X		X	X	X
30. dieldrin	2	1	2		1
31. dibromochloromethane	35	X	X	5	4
32. 2,6-di-t(butyl)benzoquinone	0.1				
33. di-n-butyl phthalate	5	0.01	0.1	0.05	
34. m-dichlorobenzene	0.5			X	X
35. o-dichlorobenzene	1			X	X
36. p-dichlorobenzene	0.5			X	X
37. 1,1 dichloroethane	X				
38. 1,2 dichloroethane	<0.2			6	<0.4
39. 1,1 dichloroethylene (vinylidine chloride)	X			X	X
40. cis-1,2 dichloroethylene	X			X	X
41 trans 1,2 dichloroethylene	X				
42. dichloromethane	X	X	X	X	X
43. diethyl malonate					0.01
44. diethyl phthalate	1	0.01			0.1
45. dimethoxymethane				X	
46. dimethyl disulfide			X		
47. di-n-octyl adipate	20.0				
48. di-(2-ethylhexyl) phthalate	30				
49. di-n-propyl phthalate	0.5				
50. ethanol		X	X	X	X
51. ethyl ether				X	X
52. p-ethyltoluene		0.05			

X - organics identified but not quantified.

*"Approximate concentrations" are explained fully in the Appendix. When organics were quantified by more than one technique or at different times the highest concentration of organics detected is reported.

Table 4 (cont.)

ORGANIC COMPOUNDS DETECTED IN SURVEY OF FIVE CITIES
(Approximate Concentrations, µg/l)

	Miami, Florida	Seattle, Washington	Ottumwa, Iowa	Philadelphia, Pennsylvania	Cincinnati Ohio
53. hexachloroethane	0.5				
54. isophorone (3,5,5-trimethyl-2-cycloheren-1-one)					0.02
55. lindane					0.01
56. methanol	X	X		X	X
57. methyl acetate		X			
58. 3-methyl butanal	X		X	X	X
59. 3-methyl-2-butanone			X		
60. 2-methyl butyl nitrile	X			X	X
61. methyl ether		X		X	X
62. methyl formate		X			
63. 3-methyl-3-pentanal			1		
64. 2-methyl propanal	X	X	X	X	X
65. 2-methyl propyl nitrile	X			X	X
66. nicotine	3.3				
67. nitromethane				X	X
68. n-pentanal			0.5		
69. 2-pentanone			0.1		
70. phenylacetic acid			4		
71. n-propylbenzene	0.05				0.01
72. n-propylcyclohexanone	0.2				
73. B-santalene		0.01			
74. α-terpineol			0.5		
75. tetrachloroethylene	0.1			X	0.1
76. 1,1,3,3-tetrachloro-2-propanone	0.2			1	0.5
77. tetramethylbenzene isomer	0.2				
78. tetramethyltetrahydrofuran			0.5		
79. toluene	X		X	X	X
80. tri-n-butyl phosphate	0.5				0.05
81. 1,1,1 trichloroethane			X		
82. 1,1,2 trichloroethane	X				
83. trichloroethylene	X		X	X	X
84. trimethyl isocyanurate					0.02
85. 1,3,5-trimethyl-2,4,6-trioxo-hexahydrotriazine					0.5
86. vinyl chloride (6)	5.6			0.27	

National Survey of Pesticides in Drinking Water

Other investigations of specific organic contaminants include an intensive nationwide survey of pesticides in drinking water. The survey's principal focus is on aldrin, dieldrin, and DDT, and the results of the survey should be useful in assessing the maximum contaminant levels to be established for these three pesticides.

The program is designed to examine samples of raw and finished water from ground and surface water supplies in three population density ranges (less than 5000, 5000 to 49,999, and 50,000 and greater) in each of the ten EPA regions. 330 supplies were selected from an inventory of approximately 40,000 community water supplies. Site selection for sampling these supplies was based on several criteria: population served, high and low pesticide potential, and treatment technology. The samples will be analyzed by gas chromatography/ mass spectrometry, coupled with a computer to identify the compounds. With this technique, it should be possible to determine what other chlorinated pesticides are present at significant levels. This analytical methodology can detect compounds in the parts-per-trillion range. EPA and contractor laboratories will analyze some duplicate samples to verify the technique and results.

The sampling began March 1, 1975, and is scheduled to be completed by mid-summer. A final report with an analysis of the significance of the findings, including populations at risk, should be prepared by early fall.

Analysis for Inorganics in Water Supplies

Many inorganic chemicals in drinking water are potentially toxic at certain concentrations. The proposed Interim Primary Drinking Water Regulations present maximum contaminant levels for 11 inorganics, including some suspected carcinogens: arsenic, barium, cadmium, chromium, cyanide, fluoride, lead, mercury, nitrate, selenium, and silver. All the water supplies sampled in the National Organics Reconnaissance Survey were analyzed for these inorganics. In addition, several other EPA projects are investigating the presence of these and other inorganic chemicals in drinking water, as discussed below. While extensive efforts have been directed to asbestos, because of the special nature of the asbestos problem these activities will be discussed in a separate section.

Analysis of Interstate Carrier Water Supplies

Until the passage of the Safe Drinking Water Act, the Federal Government's authority to regulate drinking water was limited to interstate carrier water supplies. At about three-year intervals, a survey of each of the 700 supplies is made jointly by the states and the EPA Regional Offices. At the time of the survey, a water sample is collected and analyzed for the chemicals limited by the Public Health Service Drinking Water Standards. Tabulations made of these data are published in the Chemical Analysis of Interstate Carrier Water Supply Systems. The

results published in October 1973 indicate that chromium, lead, and mercury were in some instances found in concentrations that exceed the Drinking Water Standards. Of these three, mercury most frequently exceeded the limit, but this occurred in only 1.5 percent of the samples analyzed.

Contamination of Consumer's Drinking Water

While many analyses have been made of community drinking water supplies, some studies have examined drinking water at the tap. The first comprehensive data on water quality at the consumer's tap were collected in the Community Water Supply Survey of 1969. The concentrations of arsenic, barium, cadmium, chromium, lead, selenium, and fluoride that were found in public drinking water supplies each exceeded the 1962 Public Health Service Drinking Water Standards in some instances. However, of the 2,595 distribution samples analyzed, fluoride, which most frequently exceeded the proposed limits, did so in only 2.2 percent of the samples; the lead limit was exceeded in only 1.4 percent of the samples.

Water occasionally is contaminated by metals from corroded plumbing. This contamination has been of particular concern in some communities. Special studies of the lead content in drinking water have shown that 65 percent of the homes surveyed in Boston and 24 percent of the homes surveyed in Seattle have lead in their tap water in amounts exceeding the 1962 Drinking Water Standard for lead.

In addition, EPA and the National Heart and Lung Institute are jointly studying the inorganics present in 170 community water supplies selected to be representative of U.S. water supplies. An attempt will be made to determine the effects of drinking water quality on health, especially the correlation between soft drinking water and heart disease mortality.

As part of the Agency's Environmental Radiation Monitoring System (ERAMS), measurements of tritium radioactivity are made in drinking water samples from 77 major population centers and communities near selected nuclear facilities. Results of the 1974 ERAMS survey are included in Appendix IV. In 1974, the highest observed concentration of tritium was less than 20 percent of the EPA maximum contaminant level for radioactivity in drinking water currently being prepared. The average concentration was about one percent of the proposed level. Additional data on radioactivity in community water systems should become available as States begin to implement monitoring requirements that will be established under the Interim Primary Drinking Water Regulations.

Survey of Rural Drinking Water Supplies

Section 3 of the Safe Drinking Water Act requires the Administrator to survey rural water systems to determine the quality, quantity, and availability of water supplies for rural Americans. EPA has designed a survey of 5200 randomly selected rural households to assess among other things the availability of water, water sources, and quality of drinking water.

In addition to the usual bacteriological analyses of water samples to detect the presence of contamination (total coliform, fecal coliform, fecal streptococci), chemical and radiological analyses of each water supply will be made. All samples will be analyzed for pH, nitrates, ammonia, chlorides, calcium, magnesium, sodium, lead, and sulfates. Every tenth sample will be analyzed for the inorganic chemicals in the proposed Interim Primary Drinking Water Regulations and for certain pesticides. Every twenty-fifth sample will be analyzed for gross alpha and radium 226. The survey is scheduled to be completed in June 1976; a final report is due in December 1976.

Asbestos Fibers in Water Supplies

Asbestos fibers in the drinking water in Duluth, Minnesota, have been traced to industrial discharges into Lake Superior. Monitoring studies in other locations are indicative of non-industrial sources of asbestos as well, such as asbestos-cement pipe or naturally occurring asbestos. These findings suggest that asbestos may be quite widely distributed in drinking water supplies throughout the nation.

Studies of Asbestos in Duluth, Minnesota

A few months after the presence of asbestos fibers in Duluth's potable water was confirmed in the fall of 1973, the Agency began periodic asbestos analyses of the raw water. These analyses, for amphibole mass by x-ray diffraction and for asbestos fibers by electron microscopy, demonstrated the continuing presence of asbestos fibers. In addition to these studies, an extensive lake sampling program showed that the concentration of asbestos fibers was highest near the industrial discharge and declined steadily at increasing distances from the discharge.

In the process of attempting to develop a procedure for the routine analysis of asbestos in water, EPA selected some samples from interstate water carriers. Only nine of the 63 samples (14 percent) had counts that were in excess of 5×10^5 fibers per liter. Furthermore, only five of these cities (8 percent) had counts of 1×10^6 fibers per liter. The five cities were Duluth, Minnesota; Troy, Vermont; Seattle, Washington; Skidway Island, Georgia; and San Francisco, California. Eleven (18 percent) had fiber counts below detectable limits. These findings prompted EPA to develop a nationwide asbestos sampling program now in progress.

Investigations of Asbestos from Pipe Erosion

Erosion of asbestos fibers from the walls of asbestos-cement (A/C) pipe that is used in water distribution systems may be a source of asbestos in drinking water supplies. Investigations of this possibility involve a controlled experiment with water of a known chemical quality circulated through two 100-foot lengths of A/C pipe. Weekly samples of the effluent are being analyzed by electron microscopy to determine whether or not asbestos fibers are released from the pipe wall.

Another phase of this project involves selection of locations where water low in asbestos fibers flows some distance through A/C pipe prior to use. Continuing monthly analyses of the source and tap waters should show whether or not an increase in the asbestos fiber content occurs because of passage through the A/C pipe. Three locations have been selected, and the first samples have been collected. Other systems are expected to be tested in the future.

Nationwide Asbestos Sampling Program

A nationwide asbestos sampling program is underway to determine the environmental levels of asbestos resulting from discharges from various sources. Thirty-two sampling locations have been chosen which include four major categories of asbestos discharges. A natural site category was selected because of known asbestos rock formations which may contribute significant amounts of asbestos in run-off or emissions due to natural weathering processes. Other categories include asbestos mining; mining of other ores such as talc and vermiculite which may also be sources of asbestos; and asbestos manufacturing. For all categories, both air and water samples are being taken. Over sixty sampling sites have been chosen, including the water supplies of several major cities, such as San Francisco, Denver, Chicago, Atlanta, and Dallas. The sampling has begun and a report, with the details of the analyses, should be available early in 1976.

HEALTH EFFECTS OF DRINKING WATER CONTAMINANTS

With the aid of modern analytical techniques, such as gas chromatography, mass spectrometry, and atomic absorption, many types of organic chemicals and heavy metals have been detected in drinking water for the first time. Our knowledge of the health effects of most of these contaminants, particularly in the minute concentrations which occur in drinking water, is highly inadequate. Complete analyses of the health risks involved must include evaluation of human exposure to these chemicals from all sources including contaminants in food and in the air. While the efforts described below are extensive, they represent only the beginning of the research needed to assess confidently the health effects of drinking water contaminants.

Review of Drinking Water Contaminants by the National Academy of Sciences

In fulfilling its responsibilities under the Safe Drinking Water Act, EPA has arranged for a study by the National Academy of Sciences (NAS) to provide a health basis for setting maximum contaminant levels in drinking water. While the legislation requires NAS to determine recommended "maximum contaminant levels" based on potential health effects, NAS is taking a slightly modified approach. NAS will provide information and scientific judgments concerning the health effects which might be expected at various ranges of concentrations for the contaminants. This information will enable the Administrator to determine appropriate health goals for these contaminants and then, after considering technological and economic feasibility, to establish levels for National Primary Drinking Water Regulations.

For those contaminants for which there is a sufficient data base, NAS will make recommendations concerning the relationships between contaminant levels and health effects. Among the factors the Academy will consider are the margin of safety required to protect particularly susceptible segments of the population: exposure to the contaminants by other routes; synergism among contaminants; and the relative risk of different levels of exposure to the contaminants.

The Academy will also investigate and report those contaminants which may pose a threat to human health but whose current level in drinking water cannot be determined. For those contaminants, the Academy will recommend studies and test protocols for future research. The project, initiated in April 1975, is scheduled for completion by December 16, 1976. This NAS review of drinking water contaminants should provide an overview of the drinking water problem that will be essential in determining future national strategies.

Quality Criteria for Water

In addition to the studies being conducted by the National Academy of Sciences to recommend maximum contaminant levels, EPA is developing

Quality Criteria for Water pursuant to the Federal Water Pollution Control Act Amendments of 1972 (Section 304(a)(1) of PL 92-500). These criteria are being developed to provide a scientific basis for establishing ambient water quality goals. These goals should be useful as benchmarks for setting water quality standards including State Water Quality Standards, Effluent Guidelines, and the 1979 Interim Raw Source Drinking Water Standards for the Safe Drinking Water Act (Section 1401(1)(D) of PL 93-523). Included in the list of about 60 constituents are organic and inorganic materials, including some suspected carcinogens.

Other Investigations of the Health Effects of Organics

EPA Science Advisory Board Review of Selected Organics

EPA has sought the advice of its Science Advisory Board regarding potential carcinogenic or other adverse health effects resulting from exposure to organic compounds in drinking water. Though recognizing the importance of other types of toxic action, because of time constraints the Board focused on the possible health risks from cancer. Principal attention was directed to the compounds listed in Table 5, particularly chloroform, carbon tetrachloride, chloroethers, and benzene.

Table 5

SELECTED CONTAMINANTS IN U.S. DRINKING WATER SUPPLIES

Contaminant(s)	Amounts in µg/l (ppb)	Estimated Distribution*
Carbon tetrachloride	<2 - 3	10%
Chloroform	<0.3 - 311	100%
Other Halogenated C_1 and C_2	<0.3 - 229	100%
Bis(2-chloroethyl)ether	0.02 - 0.12	low
2-chloroethylmethylether	unknown	low
Acetylenedichloride	<1	low
Hexachlorobutadiene	~0.2	low
Benzene (inc. alkylated benzenes to C_6)	<10	high
Octadecane	~0.1	high
C_8-C_{30} hydrocarbons	<1	high
Phthalate esters	~1	50%
Phthalic anhydride	<0.1	low
Polynuclear aromatics	0.001 - 1	high

*These distributions for drinking water contaminants represent very rough estimates made by the Ad Hoc Study Group of the Science Advisory Board.

The Board prefaced its Report[5] with the caveat that the chemicals that have thus far been identified in drinking water account for only a small fraction of the total organic content. Thus, the possibility exists that there may be additional substances in drinking water of equal or greater toxicological significance. The Board also expressed concern that future studies should take into account possible synergistic effects of common combinations of contaminants. Further, it recommended that a complete analysis of the problem consider data from all routes of exposure to these substances in addition to drinking water, such as dietary and occupational exposure. Some of these additional sources of exposure would likely pose a much greater potential intake than from consumption of drinking water.

The Board felt that in general for all the compounds reviewed the carcinogenicity data and experimental designs were either inappropriate or below the standard of current toxicological practice and protocols for carcinogenicity testing. Additional well-designed experimental studies to determine the carcinogenicity of lifetime exposures by ingestion are sorely needed.

The Board concluded that some human health risk does exist from exposure through drinking water although this risk is currently unquantifiable. This conclusion was based on evidence of widespread contamination of drinking water supplies, particularly from chloroform. Laboratory animal studies indicate production of hepatomas by chloroform, but it should be emphasized that experimental carcinogenesis data for chloroform are extremely limited. Carbon tetrachloride, a demonstrated carcinogen in laboratory studies, occurs in drinking water generally at much lower levels and is much less widespread than chloroform and related trihalogenated compounds. Benzene has not been clearly established to be carcinogenic in experimental animals, although epidemiological and clinical studies, largely of occupational exposures, suggest its possible carcinogenicity. Certain haloethers, chloro-olefins, and polynuclear hydrocarbons have been demonstrated to be carcinogenic in laboratory animals and have been identified in drinking water. To the very limited extent that they have been measured, however, the data indicated that the potential human dosage of these compounds from ingestion of drinking water would generally be extremely small. However, the Board noted the possibility of local situations where the dosages might be high enough to justify some concern.

Data from epidemiological studies on the contaminants of primary concern to the Board were very limited and the designs of studies were generally inadequate for a conclusive assessment of health risk. Recent studies alleging an association of high cancer incidence in New Orleans with consumption of contaminated drinking water were considered by the Board to be useful for forming hypotheses for future epidemiological studies but not indicative of any clear cancer hazard. Numerous other variables might explain the apparent associations. Indeed, experimental

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[5] A Report: Assessment of Health Risk from Organics in Drinking Water, Hazardous Materials Advisory Committee, Science Advisory Board, Environmental Protection Agency, May 19, 1975.

toxicology studies suggest that, if there were a carcinogenic risk, increased liver cancer would be a probable finding. In fact, however, this was not revealed by the epidemiological studies. As part of its recommendations to EPA, the Board suggested that epidemiological studies be undertaken to relate drinking water contamination with differences in cancer incidence or other effects in exposed populations.

Experimental Evaluation of the Toxicity of Organics

Currently, several EPA Offices are evaluating the toxic properties of individual compounds and mixtures of organics extracted from drinking water. The metabolism and toxicity of several compounds are being studied in experimental species. These compounds include bis(2-chloroethyl) ether; bis(2-chloroisopropyl) ether; dibromochloromethane; bromodichloromethane; and the homologous series of chlorinated benzenes and that of brominated benzenes. Comparative metabolic studies seek to identify the animal models that will be most predictive of the responses in man. Comparative acute and chronic toxicity studies will investigate the types and reversibility of pathological lesions, target organs, and threshold doses associated with each compound. Specialized studies will examine the possible synergistic role of the halogen-substituted benzenes.

The toxicity of mixtures of organics collected from five U.S. cities will be analyzed using several bio-assay procedures. Organic extracts that demonstrate activity that may be carcinogenic, mutagenic, teratogenic, or seriously toxic, will be chemically fractionated to isolate the active chemical(s). The compounds that are identified as the toxic agents will then undergo more definitive toxicity tests.

The long-standing tasks of obtaining, evaluating, and storing the relevant information on the toxicity of organics are being greatly expanded. Arrangements have been made with the Mutagenesis Information Center at Oak Ridge to obtain literature citations on the potential mutagenicity of the organic chemicals identified to date in drinking water. In-depth literature searches for 20 organic compounds found in drinking water will be conducted for information on teratogenicity, carcinogenicity, and physical, chemical, biological, and environmental properties.

Two other efforts are focusing on mutagenicity. Presently contractual arrangements are being made to test the mutagenic properties of 85 chemical compounds. It is anticipated that approximately 20 of these compounds will be organics found in drinking water. In vitro mutagenicity testing will be done on Salmonella, E. coli, and yeast, using metabolic activating systems derived from mammalian livers. In another study EPA will develop preliminary information on the potential mutagenicity of substances which might be produced during the ozonation process. A number of chemical compounds will be subjected to conditions similar to those encountered during disinfection processes using ozone. The ozonated product mixtures will be tested to determine the potential mutagenic effects on certain microorganisms.

In addition to these studies, it is important to note the National Cancer Institute's study of chloroform. This study is an attempt to assess the health effects of ingesting chloroform and should provide much needed data for evaluating the health risks, if any, associated with the presence of chloroform in drinking water. The study, which involves both rats and mice in a two-year experiment, is expected to be completed by early fall 1975.

Health Effects of Organics Occurring in Nature (Humic Substances)

The organics thus far identified in drinking water are believed to represent only a small percentage of the total organic concentrate recovered from drinking water. The remaining fraction is quite heterogeneous and includes mixtures of high molecular weight organics not susceptible to rigorous chemical definition.

When subjected to chlorine or ozone treatments, humic substances might produce either halogenated organic compounds or oxidized forms, including peroxides or epoxides, which may be hazardous to man. An animal feeding study concerning the carcinogenic potential of humic substances that occur naturally in water is planned. The study will test the effects of subjecting these substances to chlorination, or ozonation, or to sequential treatment with ozone and chlorine. This investigation will follow the testing guidelines of the National Cancer Institute.

Environmental Levels of Organics and Health Effects

An investigation scheduled to begin shortly will seek to identify and measure environmental levels of selected halogenated organic compounds and to determine the correlations of various levels with health effects observed in the exposed population. This study will focus on areas suspected of having high levels of these organics in the environment and areas known to have a high incidence of cancer. Comparative analyses will be made of other areas with moderate and low environmental levels of the substances. The project should be completed in the spring of 1976.

Estimating Exposure to Organics

EPA plans to explore the correlations between levels of organics that have been measured in each water supply and the number of users of each supply. Extrapolations from these data to national exposure curves will be attempted. The estimate of national exposure to organics, in conjunction with the various local exposure levels, will assist in providing a basis for estimating health risks.

Health Effects Studies of Inorganics

Some of the inorganic chemicals which investigators have suggested may be potentially carcinogenic in drinking water under certain circumstances

are arsenic, beryllium, cadmium, chromium, nickel, selenium, and nitrates. All the metals are being tested for mutagenicity; those which show mutagenic effects may be subsequently tested for carcinogenicity. Some studies and brief assessments of the carcinogenicity of these inorganics are described below.

While arsenic has been associated with the occurrence of cancer, its exact role as a carcinogen has not been determined. Exposure apparently must be quite high and occur over an extended period of time before skin cancer develops. However, at certain exposure levels arsenic is generally recognized to be acutely and chronically toxic to man. In view of the recent reduction in permissible arsenic concentrations set by the Occupational Safety and Health Administration for the workplace, EPA is reviewing the concentrations allowed in drinking water.

In addition, EPA is currently considering two studies on arsenic to help clarify risks associated with exposure to arsenic. The first, part of a larger study on various selected toxic substances, involves the relationship between environmental exposure to inorganic arsenic and health effects. Populations exposed to significant amounts of arsenic would be the subject of epidemiological studies to assist in determining the health effects of arsenic exposure. The second study under consideration would determine the body burden of arsenic in humans who consume drinking water containing arsenic at or exceeding the current limit of 0.05 mg per liter.

Nitrate concentrations in drinking water have been limited because of the possibility that infants who ingest water high in nitrates may develop methemoglobinemia. There is also a possibility that the nitrogen might combine with amines in the environment to form nitrosamines; some nitrosamines are recognized carcinogens. However, this reaction was demonstrated at much higher concentrations of nitrates than would normally occur in water. The exposure associated with the use of nitrates and nitrites as meat preservatives, for example, is believed to be at least an order of magnitude greater than the exposure associated with the presence of nitrates in drinking water.

Existing health effects evidence does not conclusively show whether selenium is carcinogenic. After a complete review of its health effects, the Food and Drug Administration last year concluded that selenium could be safely used as an additive to animal feed. Very low levels of selenium are apparently necessary for red blood cell integrity. On the other hand, some FDA critics assert there is cause for concern because several animal studies show that tumors were developed from exposure to selenium. It should be noted, however, that doses used in those experiments were very high.

Radionuclides are recognized carcinogens. Following the recommendation made by the National Academy of Sciences, EPA bases its estimates of

the health effects of radiation exposure through ingestion of drinking water on the assumption that there is no harmless dose level and that any health effects produced will be proportional to the radiation dose delivered by drinking water.

Assessment of Effects of Oral Ingestion of Asbestos

While the development of cancer from exposure to airborne asbestos has been documented by epidemiological studies, the effects of ingested asbestos have not been determined. Several current projects are studying various aspects of this problem, including asbestos absorption in the gastrointestinal tract, the possible correlation between cancer incidence and asbestos in drinking water, and the toxicology of ingested asbestos in rats.

Research on the problem of ingested asbestos in man has revealed that an excess of gastrointestinal cancer and of peritoneal (abdominal) mesotheliomas (neoplasms of the lining cells) may occur in workers exposed to airborne asbestos. Scientists believe that the workers under study ingested asbestos particles which were in their mouths and respiratory tracts and that this ingestion of asbestos is related to the incidence of cancer.

EPA is studying the passage of asbestos fibers through the gastrointestinal tract in an effort to evaluate this aspect of ingestion exposure. One study involves labelling asbestos with tritium to elucidate the mechanism of asbestos absorption.

Several studies have focused on the possible correlation between asbestos in drinking water and the incidence of cancer. Two studies of the population of Duluth, Minnesota, where the concentrations of asbestos fibers in drinking water were very high, have recorded no unusually high incidence of cancer. However, because of the long latency period between exposure and the development of the disease, these studies may have been too premature for the detection of carcinogenic effects of ingested asbestos. In one study, risk ratios were calculated for Duluth in comparison to the State of Minnesota and Hennepin County (Minneapolis). Of 21 cancer sites in the body, only cancer of the rectum had an excess that was significant and highest in the latest 5-year period of the comparison. The study concluded that this was probably not related to asbestos exposure. While cancers of the esophagus and stomach had commonly resulted from occupational exposures to asbestos, these cancers were not notably high in Duluth.

The second study was based on cancer incidence data instead of mortality and compared Duluth with the Twin Cities. There was no clear pattern of difference in gastrointestinal cancer incidence among the three cities in 1969-1971. However, there is a long lag period between initial asbestos exposure and diagnosis of asbestos-associated cancers.

A third study planned for next fiscal year would involve the efforts of the Center for Disease Control. Using the tumor registries of Connecticut and California, the investigation would identify populations exposed to asbestos in drinking water and compare their tumor incidence, especially gastrointestinal cancers, ovarian cancers, and mesotheliomas, with that of populations with smaller amounts of or without asbestos in their water.

In a very important project the National Institute of Environmental Health Sciences is funding a toxicological study of the ingestion of various asbestiform types. This four-year study, expected to begin shortly, is divided into four parts. First, about one ton each of chrysotile, crocidolite, amosite, and tremolite will be characterized and prepared. Second, lifetime feeding studies of each of the fibers (one percent of the diet) will be performed with a single strain of rats, including a positive carcinogen and other controls. For each type of fiber there will be 500 rats in the experimental group and 1000 in the controls. The third part of the study will be similar to the second part except that hamsters will be used and only chrysotile and one other fiber type will be used. The last part of the study will attempt to determine if orally ingested asbestos is carcinogenic under a particular set of physiological circumstances.

The various studies described above should contribute significantly to our understanding of asbestos and of the correlation between its physical properties, including those which are common to other substances, and potential carcinogenic effects in man.

Effects of Selected Chemicals Found in Industrial Wastes

As part of an ongoing hazardous waste management program, extensive literature surveys and evaluations of the health and environmental effects of selected hazardous materials, including some recognized or potential carcinogens, are being conducted. Effects Reports will be issued on at least 18 hazardous substances in the following sequence: mercury, asbestos, cadmium, arsenic, chromium, cyanides, PCB's, fluorides, methyl parathion, benzidine, toxaphene, selenium, copper, zinc, beryllium, and endrin. Almost all of these chemicals have been found in drinking water at various levels. To provide useful information for health risk determinations, dose-response information will be presented where data are available. Most of this work is being performed for EPA by the Oak Ridge National Laboratory. The first of the Reports considers mercury and is expected to be issued in the fall of 1975; the last of the series, endrin, is anticipated by the end of 1976.

Industrial Correlates of Cancer Mortality

This effort, being carried out in cooperation with the National Cancer Institute, involves the statistical analysis and correlation of indices of cancer incidence with indices of the concentration of selected industries on a county-by-county basis. To the extent possible, the

study will assess the relationships between each specific industry identified and increases in particular types of cancer. Consideration will be given to whether such increases are due to the effluents and emissions from these industrial plants, to occupational exposure, or to other factors, including such demographic variables as age, income, sex, race, and population density.

The study should provide a much needed broad perspective in assessing the relationships among industrial concentrations, pollutant levels (including drinking water contaminants), and cancer. A report of the initial results should be available by the end of 1975.

SOURCE IDENTIFICATION

Investigations of sources of contaminants address a variety of suspected sources such as industrial effluents, agricultural run-off, municipal waste treatment facilities, chlorination and other treatment processes, and landfills. These investigations are discussed below.

Sources of Organics

EPA is identifying substances remaining in municipal and industrial wastes and sludges after various treatment processes. This effort will provide information on the presence of substances which are potentially damaging to man and the environment; provide data on the effectiveness of various treatments; and allow identification of the sources of organics in water at the microgram per liter or greater concentrations.

Industrial Sources

Several studies of industrial effluents have produced an extensive inventory of organics which suggests that industrial sources may be major contributors to the organics found in drinking water. Two of the substances in drinking water that have been rather clearly identified as suspected carcinogens, chloroform and bis(2-chloroethyl) ether, appear in industrial wastes and not in domestic sewage, an alternate possible source. However, there is also the possibility that these compounds are formed by chlorination during the treatment of drinking water.

Extensive studies will be required to establish a direct relationship between industrial discharges and appearance of organics in drinking water. Systematic studies of the composition of industrial effluents are on-going. EPA also is considering a program that will help identify the industrial sources of discharge of organics into river basins which feed a number of public drinking water supplies. The goal of this program would be to correlate the organics appearing in particular water supplies with specific industrial discharges.

Over 200 organics identified in various drinking water supplies have been examined to determine possible point source discharges during manufacture and use; possible non-point sources; persistence; methods of removal; and gross estimates of total discharge. Some data have been collected on industrial discharges to the Potomac River Basin. A report describing these efforts, along with preliminary recommendations, should be available in the fall of 1975.

Discharges from Municipal Waste Treatment Facilities

Efforts are underway to determine to what extent municipal waste treatment practices and effluents contribute to the presence of organic chemicals in drinking water supplies.

Under contract to EPA, the Oak Ridge National Laboratory developed a procedure for the separation and tentative identification of refractory

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organics from municipal waste treatment facilities. The procedure which is capable of detecting organics at the microgram-per-liter level was applied to the study of primary and secondary effluents at the Oak Ridge facility. In primary effluents, 55 compounds were identified with an additional 30 or more detected but not identified. The identified substances include simple carbohydrates, amino acids, and other components apparently of metabolic origin. These same substances were found in both chlorinated and unchlorinated effluents. Table 6 provides a list of the identified compounds.

Table 6

ORGANIC CHEMICALS IDENTIFIED IN PRIMARY WASTE TREATMENT EFFLUENT

Ethylene glycol
Glucose
Erythritol
Phenylalanine
5-Acetylamino-6-amino-3-methyluracil
Theobromine
Hypoxanthine
Adenosine
3-Methylxanthine
2-Deoxyglyceric acid
Quinic acid
2-Deoxytetronic acid
3-Deoxyerythropentonic acid
Ribonic acid
Uric acid
3-Hydroxyphenylhydrazylic acid
4-Hydroxybenzoic acid
4-Hydroxyindole
Maltose
Glycerine
Urea
Uracil
N-Methyl-2-pyridone-5-carboxamide
7-Methylxanthine
Xanthine
1,7-Dimethylxanthine
Caffeine
3-Hydroxybutyric acid
1-Methylxanthine
Glyceric acid
2,5-dideoxypentonic acid
Oxalic acid
Succinic acid
Phenylacetic acid
Benzoic acid
4-Hydroxybenzoic acid
o-Phthalic acid
Galactose
Galacitol
N-Methyl-4-pyridone-3-carboxamide
Tyrosine
Thymine
Inosine
Copper (II) acetate (binuclear)
Guanosine
3-Deoxyarabinohexonic acid
1-methylxanthine
4-Deoxytetronic acid
3,4-Dideoxypentonic acid
2-Hydroxyisobutyric acid
Phenol
4-Hydroxyphenylacetic acid
2-Hydroxybenzoic acid
Indican
p-Cresol

In unchlorinated secondary effluents 33 compounds were detected. Thirteen were identified. Ten of these were also identified in primary effluents. The 13 substances are listed in Table 7.

Table 7

ORGANIC COMPOUNDS IDENTIFIED IN SECONDARY WASTE TREATMENT EFFLUENT

Glycerin
5-Acetylamino-6-amino-3-methyluracil
7-Methylxanthine
1,7-Dimethylxanthine
Catechol
3-Hydroxindole
Uracil
1-Methylinosine
Inosine
1-Methylxanthine
Succinic acid
Indole-3-acetic acid
p-Cresol

Samples of both primary and secondary effluents were chlorinated under conditions simulating plant conditions and analyzed for chlorinated

compounds. Of 62 chlorinated compounds which were detected, 15 have been identified and are listed in Table 8. In addition to the Oak Ridge study, work being done at North Texas State University has identified 12 polychlorinated compounds in superchlorinated domestic wastes (Table 9) and detected 16 other chlorinated compounds which have not yet been identified. Table 10 identifies acid fractions of domestic wastes.

Table 8

COMPOUNDS IDENTIFIED IN CHLORINATED PRIMARY AND SECONDARY EFFLUENTS

5-Chlorouracil
8-Chlorocaffeine
8-Chloroxanthine
5-Chlorosalicylic acid
2-Chlorophenol
4-Chlorobenzoic acid
3-Chlorobenzoic acid
and/or 3-Chlorophenol
4-Chloro-3-methylphenol
5-Chlorouridine
6-Chloro-2-aminopurine
2-Chlorobenzoic acid
4-Chloromandelic acid
4-Chlorophenylacetic acid
4-Chlorophenol
4-Chlororesorcinol

Table 9

COMPOUNDS IDENTIFIED IN SUPERCHLORINATED MUNICIPAL WASTEWATERS

Trichlorotoluene
Hexachloroethane
1,1,1,3,3-Pentachloro-2-propanone
2,4-Dichloroethylbenzene
o- and p-Chloroethyl benzene
2,4,5-Trichloropitenetole (3 isomers)
1,2-Dichloropropane
o- and p-Dichlorobenzene
(Chloromethyl)butene (2 isomers)

Table 10

ORGANIC SUBSTANCES FOUND IN THE ACID FRACTION OF DOMESTIC SEWAGE TREATMENT EFFLUENTS

Butyric acid
Isovaleric acid
Caprylic acid (C_8)
Lauric acid (C_{12})
Pentadecanoic acid (C_{15})
Margaric acid (C_{19})
Nonadecanoic acid (C_{19})
Behenic acid (C_{22})
Oleic acid
Anteisomargaric acid
Hydroxypalmitic acid
Phenylacetic acid
Phenylpropionic acid
Pentachlorophenol
Isobutyric acid
Enanthic acid (C_7)
Capric acid (C_9)
Myristic acid (C_{14})
Palmitic acid (C_{16})
Stearic acid (C_{18})
Arachidic acid (C_{20})
Palmitoleic acid
Anteisopentadecanoic acid
Hydroxymyristic acid
Hydroxystearic acid
Salicylic acid
2-(4-chlorophenoxy)-2-methyl propionic acid

As part of the industrial source program described earlier, a preliminary literature search has been conducted to determine which organics have been identified in municipal waste treatment effluents and which are likely to be present either from industrial discharge or as a result of biological treatment or chlorination. The preliminary results show that 23 of the organics identified in drinking water have been positively identified in municipal waste treatment effluents; an additional 27 may be found as intermediates or final products of biological treatment; and 42 could be produced during chlorination of treatment effluents.

In addition to determining whether municipal waste treatment practices and effluents are a significant source of organics in water supplies, investigations are also directed to whether control can be achieved by regulating industrial discharges to sewer systems or whether further treatment of municipal waste treatment effluents is required. A preliminary report describing these efforts, along with recommendations of near-term steps that could be taken to minimize the problem, will be completed in the fall of 1975.

Chlorination of Water Supplies

As yet, there is no acceptable substitute for chlorination as a residual disinfectant, and the health hazards of foregoing chlorination would be severe. At the same time, concern is increasing over the effect of chlorination on organic materials found in natural and waste waters. In 1973, the following compounds were identified as formed by chlorination of water supplies: chloroform, bromodichloromethane, dibromochloromethane, and bromoform. At that time naturally occurring humic substances were postulated to be precursors to the formation of these trihalomethanes. The maximum concentrations found were: chloroform, 54.0 µg/l; bromodichloromethane, 20.0 µg/l; dibromochloromethane, 13.3 µg/l; and bromoform, 10.0 µg/l.

A later study confirmed the presence of these trihalomethanes in a variety of finished drinking waters from Ohio, Indiana, and Alabama. It prompted studies to determine which factors influence the rate and quantity of the formation of trihalomethanes during chlorination, and which other halogenated compounds might be formed at the same time.

One study compared the rate and extent of chloroform formation when chlorine was added to raw river water, dual-media filtered water, and water treated by granular activated carbon. These experiments were carried out at constant pH and at 25°C. When sufficient chlorine was added to satisfy the chlorine demand for the duration of the experiment, chlorination of raw river water yielded approximately seven times as much chloroform as did chlorination of the dual-media filtered water, and approximately 80 times as much as did chlorination of the fresh granular activated carbon filter effluent (207 µg/l, 32 µg/l, and 2.7 µg/l, respectively, in 7+ days). The rate of chloroform formation in the river water was approximately 10-15 µg/hr for the first six hours. Researchers have not yet determined which substances are removed from the raw river water during alum coagulation, settling, and dual-media filtration that reduces the rate and extent of chloroform formation upon chlorination.

Other studies investigated the chlorination of approximately 50 ug/l of nitromethane, benzene, toluene, and m-xylene. Under the conditions of the test, nine days of storage at 25°C, nitromethane was readily converted to chloropicrin, and m-xylene was readily converted to chloroxylene. Benzene did not react with the chlorine under these conditions, and toluene produced chlorotoluene rather slowly. These studies indicate that other chlorination by-products can occur during the chlorination process and should not be overlooked in future studies.

Controlled studies of this type will continue in an attempt to define specific precursors of the trihalomethanes, and the conditions under which the formation of these substances is enhanced or retarded. Investigations dealing with the formation of other halogenated organics by chlorination of water supplies will also continue.

Contamination by Agricultural Chemicals

Two projects address the contamination of drinking water by agricultural chemicals. One is an assessment of the magnitude and scope of the impact on drinking water supplies of intensive application of pesticides and fertilizers in underground water recharge areas. On the basis of very limited data now available, no significant problems have been identified resulting from potassium or phosphorus nutrients. Problems related to nitrogen seem to be localized. Ground water data on contamination from pesticides or their residues are too limited for comment at this time. The initial phase of the study should be completed in November 1976. A second project is an attempt to determine whether various water treatment techniques effectively remove pesticides found in raw water supplies. An analysis of the pesticides present in raw and finished water should indicate whether there are statistically significant differences in treatment efficiency.

Other Non-point Sources of Organics

EPA is attempting to estimate the contribution of non-point sources to the total organic compounds found in river basins which feed drinking water supplies. The purpose of this activity is to help determine whether significant abatement can be achieved by regulation of point source discharges or whether direct treatment of drinking water supplies is necessary.

A total of 154 organic chemicals identified in various drinking water supplies have been studied preliminarily to determine possible non-point sources of discharge, persistence, and methods of removal. A report describing these efforts should be available in the fall of 1975.

Solid Waste Sources

Hazardous Waste Management Practices of Major Industries

The generation, treatment, and disposal of hazardous wastes of the following 13 industry categories are currently under investigation:

Pharmaceuticals; Paint and Allied Products; Storage and Primary Battery Manufacturing; Inorganic Chemicals; Petroleum Refining; Primary Metals; Metals Mining; Electroplating and Metal Finishing; Organic Chemicals; Pesticides, and Explosives; Textiles; Rubber and Plastics; Leather Tanning and Finishing; and Machinery (except Electrical). These industry studies relate to the problem of carcinogens in drinking water insofar as they clarify the types and quantities of recognized and potential carcinogens that are disposed on land and subsequently might be transmitted to nearby surface and ground waters. The first studies (storage and primary battery manufacturers) have been completed; the last in the series is expected to be issued by the summer of 1976.

Investigations of Various Land Disposal Practices and Water Contamination

EPA has several investigations underway to clarify the possible correlation between disposal practices and contamination of water supplies. Monitoring of surface and ground waters at dumps and sanitary landfills is being conducted to determine whether the waters have been contaminated by materials present in the dumps or landfills. As a result of the contamination of surface and ground waters, drinking water may be contaminated. Monitoring has begun at seven of the 11 sites selected and should be completed by December 1975. Preliminary results from one dump indicate that the ground water below the site has been polluted. The results from other sites will probably vary depending on climatological and physical parameters.

Another project is entitled "Development of a Data Base for Determining the Prevalence of Migration of Hazardous Chemical Substances into the Groundwater at Industrial Waste Land Disposal Sites." This study is expected to document the migration of hazardous substances, including some suspected carcinogens, from approximately 75 industrial land disposal sites, including dumps, landfills, lagoons, pits, and basins, into the Nation's groundwaters. The primary objective of this effort is to provide data for developing future land disposal guidelines and standards. This investigation is expected to begin in the fall of 1975 and to conclude in the summer of 1977.

TREATMENT TECHNIQUES FOR CONTROLLING CONTAMINANTS IN DRINKING WATER

Removing Organics with Granular Activated Carbon

To date, the major treatment technique investigated for the removal of general and specific organics from drinking water has been granular activated carbon. About ten years ago, partially exhausted granular activated carbon was shown to remove dieldrin, lindane, 2,4,5-T, DDT, and parathion to below detectable limits. About the same time, fresh granular activated carbon used to treat Kanawha River water was shown to remove bis(2-chloroethyl) ether, 2-ethyl hexanol, bis(2-chloroisopropyl) ether, a-methylbenzyl alcohol, acetophenone, isophorone, and tetralin. More recent studies have shown that fresh granular activated carbon receiving finished water from Evansville, Indiana, removed all detectable bis(2-chloroethyl) ether and bis(2-chloroisopropyl) ether.

For about seven months, a coal-base granular activated carbon column, 28 inches deep, has been receiving Cincinnati tap water spiked with approximately 30 µg/l of naphthalene. After this time period, the 50 percent removal point for naphthalene was only approximately two inches down the column. Two 28-inch deep columns of granular activated carbon, one coal-based and the other lignite-based, have been receiving Cincinnati tap water. The purpose of this test has been to determine the effectiveness of the two types of granular activated carbon for the removal of trihalomethanes. Both columns removed all of the trihalomethanes for about one month of operation, and then some chloroform began appearing in the effluent. The current experience indicates that the effective life of carbon in removal of organics may be somewhat limited.

At the present time, a pilot plant made of stainless steel and glass is treating 400 ml/min of unchlorinated Ohio River water in an attempt to demonstrate how to remove effectively trihalomethane precursors from water so that chlorine can be used as a disinfectant without the formation of trihalomethane. Ozone is also being evaluated as a possible alternative to chlorine for post-treatment disinfection.

Future plans include pilot and full scale research designed to indicate the effectiveness of granular activated carbon and other organic removal unit processes for the removal of specific raw water contaminants of concern.

Techniques for Controlling Inorganics

Techniques for the control of concentrations of various inorganics have been studied by EPA. Of the substances studied thus far, only arsenic, asbestiform fibers, and radium 226 have been considered as suspected carcinogens in drinking water. Treatment technology studies for these substances have been conducted. Arsenic was studied in bench and pilot scale investigations by spiking Ohio River water and ground water from Glendale, Ohio, with concentrations of arsenic from two to ten times the limits in the proposed Interim Primary Drinking Water Regulations.

Information on the treatment potential of various techniques for radium 226 removal was obtained by monitoring several water treatment plants in Iowa that are treating water that is naturally high in radium 226.

Studies on mercury, cadmium, selenium, and chromium were similar to those described above for arsenic. For the barium removal studies, both bench-scale and pilot plants will be used. In all the studies, the techniques that were found to be among the most effective for removing the inorganic contaminants included excess lime softening, ion exchange, and ferric sulfate coagulation.

Filtration Techniques for Asbestos

The methods being studied for the removal of asbestiform fibers are mixed media and diatomite filtration employing alum and polyelectrolytes. Pilot plant research conducted in 1974 at Duluth, Minnesota, demonstrated that asbestiform fiber counts in Lake Superior water could be effectively reduced by these filtration techniques. During the study, engineering data were also obtained for making cost esimates for construction and operation of both granular media and diatomaceous earth filtration plants ranging in capacity from 0.03 to 30 million gallons per day. Both amphibole and chrysotile can be markedly reduced by both filtration techniques.

COSTS AND ECONOMIC IMPACT OF CONTROL TECHNOLOGY

EPA has begun to evaluate the potential costs associated with alternative treatment technologies used for removing drinking water contaminants. The cost estimates from various studies now underway or proposed will be issued as they become available. Estimates of the cost impact of the Interim Primary Drinking Water Regulations proposed on March 14, 1975, will be included in the promulgated Regulations to be published in the near future. These estimates are based on economic analyses of the costs associated with limiting bacterial, inorganic, and organic contaminants at the levels specified in the Regulations.